PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Functional Comparison Between Predictions of a Chinook Salmon Model and Monitoring Data in the Tuolumne River, California (formerly, Testing and Improvement of the ORCM Chinook Salmon Model)

Contract #: 500-02-004, UC MR-035-03
Contractor: Oak Ridge National Laboratory
Grant Amount: $72,813
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The Issue

Various models have been developed to predict the effects of hydropower operations on fish populations. Hydropower generators and resource management agencies in California have recently expressed interest in using the Oak Ridge Chinook Model (ORCM) to better understand how their decisions about seasonal and annual patterns in river flow will influence salmon production. In addition, the financial problems and energy deficits experienced by California during the late 1990s highlight the importance of understanding the other side of the equation—the loss of energy capacity associated with regulated flows. This project seeks to develop a better-tested quantitative tool for those making decisions about California's aquatic and energy resources.

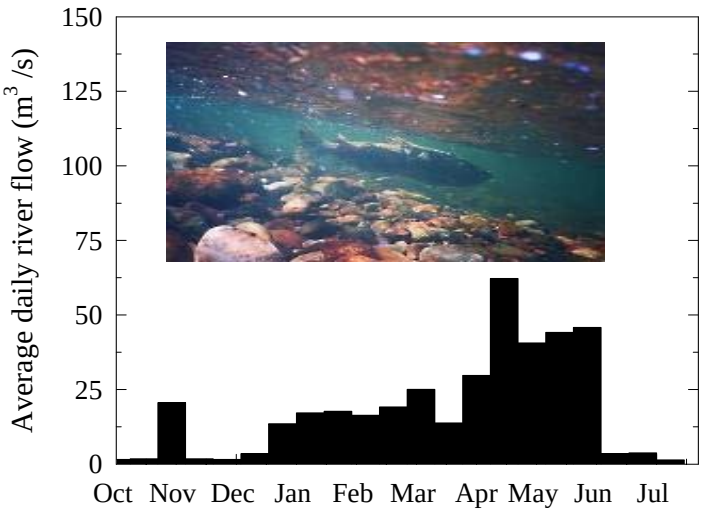

Figure 1. ORCM-predicted seasonal flow regime to maximize production of Chinook salmon outmigrants with total annual flow constrained less than or equal to 489 hm^3 (489 million cubic meters or 400,000 total acre feet)

Project Description

The goal of this project was to test and improve an existing population model (the ORCM) for Chinook salmon (*Oncorhynchus tshawytcha*). The research team compared two factors—the model's predictions of year-to-year differences in juvenile salmon production and of the timing of spring outmigration—against historic field data collected by the California Department of Fish and Game for the Tuolumne River since 1995. The goal of this comparison was to highlight

inadequacies that could be rectified by adjusting parameter values or altering the way processes are represented and revise the model accordingly.

The research team also added to the ORCM the capability to estimate hydropower generation. This feature made it possible to evaluate tradeoffs between the water flows necessary for salmon production and hydropower generation.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound energy.** This research will enable hydropower operators to quantify the expected increase in Chinook salmon produced from rivers and the expected change in hydropower generation associated with flow adjustments. The ORCM has already been used to predict optimal salmon-friendly patterns of seasonal flow (Figure 1). This research can potentially reduce uncertainty in the model's predictions of salmon production, thereby enabling improved decision making in scheduling environmental flows.

- **Providing reliable energy.** This project will incorporate the value of power generation into the ORCM, thereby enabling the model to better optimize the balance between salmon production and energy production.

Results

Empirical modeling proved useful as a tool for imputing missing field measurements and functional validation of the ORCM. Researchers identified methods for comparing model predictions with field estimates that can be used to fill in autocorrelated data series that have gaps. The model-data comparison using filled-in field data found timing of smolt outmigration was similar between model and data. ORCM predictions of smolts per spawner were similar to rotary screw trap (RST)[1]-based estimates for 1997, 1998, and 2005—but they were much higher for the years 2000–2004. The duration of the project was not long enough to allow for iterative model improvements that might reduce discrepancies. Two hypotheses suggested by the research team's model-data comparison, for future consideration, were that (1) the density-dependent mortality may be weaker in the model than in the field, or (2) fish kills resulted in lower-than-predicted juvenile survival in years 2000–2004.

The functional comparison showed agreement between the RST data and ORCM model in the relative lack of importance of flow variables, which had small but significant effects on the number of smolts migrating on a given day. Fall flow variables were better predictors of model outmigrant counts than RST counts, and spring flow variables were better predictors of RST counts than model-predicted counts, suggesting other avenues of exploration. The number of spawners in fall and fall flows were correlated, suggesting that a longer time series with years that "break" the usual correlation between these variables would help to differentiate their effects. The researchers conclude that a longer process of monitoring, comparison, and refinement involving a longer time series of field data (preferably with higher capture efficiencies) is needed to improve understanding of salmon smolt production in this river and to

[1] A rotary screw trap (RST) is a floating device in which fish are trapped and held alive in a box for collection.

reap the benefits of the ORCM model as a predictive tool. Long-term environmental monitoring data are essential to the development process, and for monitoring data to be useful to model development, they should be designed with that use in mind.

This research:

- developed two methods for reducing uncertainty in estimated salmon production, based on RST data,
- developed methods and tools for a functional comparison of model predictions and field monitoring-based estimates,
- identified future directions for improving ORCM predictions during some years, based on functional model-data comparisons,
- added the capability for the ORCM to simulate energy generation, which permits simultaneous evaluation of flow regime impacts on the production of salmon and energy, and
- illustrated the value of a continued feedback between environmental monitoring design and predictive model development.

The methods demonstrated here can be used in future to evaluate other recruitment models against rotary screw trap data for this river and other rivers in California. The study characterized model-data discrepancies and reduced uncertainty in RST estimates.

Final Report

The final report for this work, *Functional Comparison Between Predictions of a Chinook Salmon Model and Monitoring Data in the Tuolumne River, California* (CEC-500-2006-098) is posted in two files (the main report, and an attachment) on the California Energy Commission's website, at www.energy.ca.gov/2006publications/CEC-500-2006-098/CEC-500-2006-098.PDF and www.energy.ca.gov/2006publications/CEC-500-2006-098/CEC-500-2006-098-AT1.PDF.

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